

Thinning strategies for ‘Elstar’ apples – Experiences with ammonium thiosulphate, calcium hydroxide and benzyladenine

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Abstract ‘Elstar’, the most widely grown apple variety in the Netherlands, requires adequate fruit thinning to obtain regular bearing and the commercially desired fruit size and fruit quality. During several years studies have been carried out to look for alternative thinning methods to replace carbaryl, an insecticide which also induced thinning when applied to young fruitlets, but that is no longer registered in the Netherlands. During recent years research on apple thinning has focused on the use of ammonium thiosulphate (ATS) as a flower thinner combined with 6-benzyladenine (BA) as a fruitlet thinner. This paper reports on a trial in which the fruit thinning efficacy of this combined treatment with ATS and that of BA on its own were evaluated. In addition, the use of slaked lime ($\text{Ca}(\text{OH})_2$) to cover the leaves and reduce leaf photosynthesis at three different times during fruitlet development was tested, alone or in combination with an application of BA. The best chemical thinning treatment of this trial was the combination of 3 applications of ATS during flowering followed by BA at a fruit size of 13.8 mm. This treatment gave 82% of the thinning necessary to obtain the target fruit load. This treatment also effectively improved fruit size distributions, fruit colour and internal fruit quality. Slaked lime did not thin ‘Elstar’ effectively, most probably because it did not cause sufficient reduction of light interception by the canopy.

Keywords Thinning · Ammonium thiosulphate · ATS · Calcium hydroxide · Benzyladenine · Apple · Elstar

Ausdünnungsstrategien für die Apfelsorte ‘Elstar’ – Erfahrungen mit Ammoniumthiosulfat, Calciumhydroxid und Benzyladenin

Zusammenfassung ‘Elstar’, die wichtigste Apfelsorte in den Niederlanden, benötigt regelmäßige Fruchtausdünnung, um einen regelmäßigen Ertrag sowie Früchte der gewünschten Größe und Qualität zu produzieren. Seit mehreren Jahren wird nach einem Ersatz für das Insektizid Carbaryl gesucht, welches eine gute Ausdünnungswirkung auf junge Früchte besitzt, aber in den Niederlanden nicht mehr genehmigt ist. In jüngerer Vergangenheit hat sich die Forschung der Apfelausdünnung auf Ammoniumthiosulfat (ATS) als Blütenausdünnung und die Kombination von ATS mit 6-Benzyladenin (BA) als Fruchtausdünnung konzentriert. Die vorliegende Arbeit berichtet über Versuche zur Fruchtausdünnungsleistung dieser beiden Produkte im Vergleich mit der von BA allein. Zudem wurde versucht, die Photosyntheseleistung der Blätter an drei verschiedenen Zeitpunkten der Fruchtentwicklung durch einen Belag mit Löschkalk herabzusetzen, allein oder in Kombination mit BA. Die beste chemische Ausdünnung dieser Versuche war eine Kombination aus 3 ATS-Behandlungen während der Blüte, gefolgt von einer BA-Spritzung bei einer Fruchtgröße von 13,8 mm. Diese Behandlung ergab 82% des zum Erreichen der Zielfruchtzahl nötigen Ausdünnungseffekts und führte zu einer effektiven Verbesserung der Fruchtgrößenverteilung, Fruchtausfärbung und internen Fruchtqualität. Löschkalk führte zu keiner effektiven Fruchtausdünnung von ‘Elstar’; wahrscheinlich wurde der Lichtdurchlass nur unzureichend verringert.

Schlüsselwörter Ausdünnung · Ammoniumthiosulfat · ATS · Calciumhydroxid · Benzyladenin · Apfel · Elstar

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Introduction

'Elstar', the most widely grown apple variety in the Netherlands, requires adequate fruit thinning to obtain regular bearing and the commercially desired fruit size and fruit quality. For many years carbaryl has been the most used chemical thinner used to thin 'Elstar' trees that set more than the target fruit load of 100 fruits per trees for a standard plantation with a tree density of 3,333 trees/ha ($3.00\text{ m} \times 1.00\text{ m}$). In recent practical field trials ammonium thiosulphate (ATS), ethephon, and 6-benzyladenine (BA) were shown to be effective thinning agents for 'Elstar' (Maas & Peeters 2002; Maas & van der Steeg 2002). During recent years thinning trials have been focused on the use of ATS during flowering followed by BA at approx. 10–12 mm fruitlet diameter. In addition trials have been carried out to evaluate the possible use of suspensions or dyes to cover the leaves and reduce light interception. The aim of these trials was to enhance natural fruit drop by temporary reduction of photosynthesis (Fig. 1), an approach which has been demonstrated to thin 'McIntosh' apples when the trees were exposed for a few days to low light levels by the use of shade nets (Byers 2002).



Fig. 1 Application of slaked lime ($\text{Ca}(\text{OH})_2$) aimed to increase fruit drop by reduction of photosynthesis (Photo: Frank Maas, PPO-Randwijk, NL)

Material and Methods

Table 1 and Table 2 show the main data of the trial.

Results

In spring 2006 the trees used for the trial had on average 245 flower clusters each (Table 3). In the hand-thinning treatment the average number of fruits/tree removed by hand to obtain the target fruit load of about 100–110 fruits was 164. At harvest, the mean fruit number of the hand-thinned trees was 119 fruits/tree, just a few fruits above the target fruit load. Final fruit set of the hand-thinned trees was 55 fruits/100 flower clusters.

Trees treated with ATS and BA (treatment 2) yielded on average 148 fruit/tree, fruit set at harvest being 69 fruits/100 flower clusters. Thus, compared to hand thinning, the use of ATS + BA reduced the requirement for hand



Fig. 2 A tunnel sprayer was used to apply ATS during flowering (Photo: Frank Maas, PPO-Randwijk, NL)

Table 1 Main data of the trial**Experimental field**

Species:	apple
Cultivar:	Elstar
Rootstock/interstock:	M.9
Year of planting:	2001
Planting distance (m):	3 × 1.00 m
Planting system:	single row
Row orientation:	north-south
Tree shape:	spindle
Tree height/width (m):	2.25 m
Growth vigour:	moderate
Pollinizer(s):	Cox

Experimental design

Statistical design:	block design
Treatments:	9
Trees/plot:	8
Observation trees/plot:	1
Replicates:	1

Method

Spray equipment:	Knapsack sprayer (BA, Ca(OH) ₂), Tunnel sprayer (ATS) (Fig. 2)
Dilute/concentrate:	dilute (BA, Ca(OH) ₂), concentrate (ATS)
Other relevant data:	–

Description of treatments

1. Handthinned, 8 weeks after full bloom
2. ATS (3 × during flowering) + BA (150 mg/l at 10–12 mm fruit diameter)
3. BA (150 mg/l at 10–12 mm fruit diameter)
4. Ca(OH)₂ (100 g/l, 4 weeks after full bloom)
5. Ca(OH)₂ (100 g/l, 5 weeks after full bloom)
6. Ca(OH)₂ (100 g/l, 6 weeks after full bloom)
7. treatments 3 + 4
8. treatments 3 + 5
9. treatments 3 + 6

Phenology dates 2006:

1st open flower:	May 5
full bloom:	May 8
end of bloom:	May 13

Observation dates 2005:

Flower clusters per tree:	May 4
Hand thinning:	July 3
Harvest:	September 18–19

Table 2 Used chemicals and circumstances in 2006

Chemicals									
trade name		active ingredient		Concentration(s) used a.i.				Additive +/–	
ATS		98% ammoniumthiosulphate		12 kg/ha				1.5 kg/ha Captan	
MaxCel		1.9% 6-benzyladenine (BA)		150 ppm (mg/l)				–	
Supercalco 95		98% Ca(OH) ₂		100 g/l				0.5% corn starch	
Circumstances 2006									
Treatm.	Date	Stage	Hour	Tmean (°C)	Tmax (°C)	RH (%)	Wind ^{c)}	Sky ^{d)}	L/tree
1	03/07	FB ¹ + 56 days	–	23.7	30.1	47	E 3.1	clear	–
2	08/05	FB ow ²	11:30	17.7	24.5	50	ESE 5.3	moderately	0.06
2	09/05	FB ow + 1 day	16:00	18.3	25.0	47	ENE 3.8	moderately	0.06
2	11/05	FB ow + 3 days	11:30	16.0	25.8	46	NE 2.2	clear	0.06
3	02/06	13.8 mm ³	12:45	12.7	18.9	72	NNW 2.1	very cloudy	0.45
4, 7	07/06	FB + 60 days	13:30	13.9	21	73	NNW 1.5	very cloudy	0.62
5, 8	15/06	FB + 68 days	10:30	13.3	15.5	90	NNW 2.5	very cloudy	0.62
6, 9	20/06	FB + 73 days	10:30	19.5	23.4	69	SW 3.9	moderately	0.62

^{c)} abbreviated direction and speed (m/s); ^{d)} clear, lightly, moderately, very cloudy

¹ FB = full bloom; ² ow = old wood; ³ average diameter of 25 fruits on old wood and 10 fruits on 1-year wood

Table 3 Results thinning treatments on fruit production ‘Elstar’ in 2006

Treatment	#Flower clusters/ tree in 2006	#Fruits/tree		#Fruits/100 flower clusters		Yield kg/tree		Mean fruit- weight (g)	
1	248	119	a	55	a	20.8	a	176	e
2	246	148	ab	69	ab	26.8	b	181	e
3	243	182	bc	91	bc	28.6	bc	166	de
4	242	241	df	116	bc	27.7	bc	115	a
5	241	272	f	128	c	32.2	bc	120	a
6	242	266	ef	128	c	33.3	c	126	ab
7	255	221	ce	104	bc	31.2	bc	143	bc
8	242	193	bd	94	bc	28.2	bc	152	cd
9	242	214	cd	102	bc	30.0	bc	142	bc
F-test	ns	$p < 0.001$		$p < 0.001$		$p < 0.01$		$p < 0.001$	
LSD 0.05		49		23		5.9		22	

thinning by about 82%. Using BA only (treatment 3), the trees produced on average 182 fruits, i.e. BA reduced hand-thinning requirement by 62%. With 91 fruits/100 flower clusters, fruit set at harvest significantly exceeded (1.6 times) that of the hand-thinned trees. Treatment with slaked lime ($\text{Ca}(\text{OH})_2$) 4, 5 or 6 weeks after full bloom yielded about 260 fruits per tree, with a final fruit set of ca. 124 fruits/100 flower clusters. Combination of slaked lime and BA slightly reduced the number of fruits per tree and number of fruits/100 flower clusters to about the same level of the treatment with BA only.

Total fruit yield at harvest varied between 20.8 kg/tree for the hand-thinned trees and about 31 kg/tree for the trees treated with slaked lime. The combination of slaked lime and BA did not significantly affect yield, but increased the average fruit weight from ca. 120 g (slaked lime only) to ca. 146 g (slaked lime + BA). The highest average fruit weight (181 g) was obtained for the trees treated with ATS and BA, but did not significantly differ from that of the hand-thinned and BA-treated trees.

Size grading of the apples (Table 4) resulted in the highest percentages of fruits with a diameter above 70 mm and highest size index for the hand-thinned trees and trees treated with ATS + BA. Treatment with BA only resulted in a slightly, but not statistically significant, lower percentage of fruits above 70 mm. The size index of these fruits was

also quite similar to those of the fruits of the hand-thinned and ATS + BA treated trees. Trees treated with slaked lime only produced the smallest fruits. Combination of slaked lime and BA resulted in a fruit size distribution similar to that of trees treated with BA only.

Sorting out the fruits on basis of the amount of blush colour (Table 5) demonstrated that hand thinning resulted in the highest colour index and highest percentage of fruits with more than 75% of blushed skin area. On average, fruits from trees treated with ATS + BA had a slightly lower colour index and percentage of fruits more than 75% blush area, but the difference with the hand-thinned trees was not statistically significant. Blush colour of the BA-treated trees was significantly less than that of the hand-thinned and ATS + BA treated trees. However, fruit from the BA-treated trees had much more blush colour than the fruits of trees treated with slaked lime or slaked lime + BA.

Fruit background colour, firmness, sugar, starch and acid content differed most distinctly between the trees thinned by hand, ATS + BA or BA and those treated with slaked lime, a product that hardly produced any thinning effect (Table 6). The levels of sugars, acids and starch were positively related to the degree of thinning. Thus, the highest values were observed in fruits of trees thinned by hand, followed by trees treated with ATS + BA and BA only. The lowest values were observed for trees treated with slaked lime only.

Table 4 Results thinning treatment on fruit size distribution ‘Elstar’ expressed as % of total yield

Treatm.	< 60 mm	60–65 mm		65–70 mm		70–75 mm	75–80 mm		80–85 mm		> 85 mm	> 70 mm		Size index ¹	
1	0.3	1.4	a	6.9	a	30.3	47.2	c	12.9	b	1.0	91.4	c	565	bc
2	0.2	0.7	a	4.9	a	18.7	40.1	bc	28.6	c	6.8	94.2	c	611	c
3	0.1	3.4	a	18.2	a	27.9	27.9	b	16.4	b	6.1	78.3	bc	554	bc
5	8.2	23.0	b	36.4	b	24.4	7.7	a	0.5	a	0.0	32.5	a	402	a
8	6.9	9.6	a	17.8	a	25.0	29.4	b	9.8	ab	1.5	65.7	b	496	b
F-test	ns	<i>p</i> <0.001		<i>p</i> <0.01		ns	<i>p</i> <0.001		<i>p</i> <0.001		ns	<i>p</i> <0.001		<i>p</i> <0.001	
LSD 0.05		9.5		15.0			15.8		10.0			23.9		77	

¹ size index = $(\% < 60 \times 2) + (\% 60-65 \times 3) + (\% 65-70 \times 4) + (\% 70-75 \times 5) + (\% 75-80 \times 6) + (\% 80-85 \times 7) + (\% > 85 \times 8)$

ns = not significant. Values within a column followed by different letters differ significantly

Table 5 Results thinning treatments on blush colour of ‘Elstar’ expressed in blush classes as % of total yield

Treatm.	< 10% blush area		10–33% blush area		33–50 % blush area		50–75% blush area		> 75% blush area		> 33% blush area		> 50% blush area		Colour index ¹	
1	2.1	a	9.3	a	19.6	a	32.0	cd	37.1	d	88.6	c	69.0	c	486	c
2	4.0	ab	12.8	a	23.9	a	37.2	d	22.1	c	83.2	c	59.3	c	450	c
3	8.5	b	18.4	b	32.9	b	26.1	bc	14.1	bc	73.1	b	40.2	b	401	b
5	17.5	c	24.7	c	34.5	b	19.6	a	3.8	a	57.8	a	23.3	a	338	a
8	15.0	c	21.3	bc	30.2	b	24.0	ab	9.5	ab	63.8	ab	33.6	ab	366	ab
F-test	$p < 0.001$		$p < 0.001$		$p < 0.001$		$p < 0.001$		$p < 0.001$		$p < 0.001$		$p < 0.001$		$p < 0.001$	
LSD 0.05	5.5		5.1		5.4		6.5		10.2		9.4		11.7		40	

¹ colour index = $(\% < 10 \times 1) + (\% 10 - 33 \times 2.5) + (\% 33 - 50 \times 3) + (\% 50 - 75 \times 4) + (\% > 75 \times 5)$;

ns = no significant. Values within a column followed by different letters differ significantly

Table 6 Effect of thinning treatments on firmness, sugar and starch content, acidity and background colour of ‘Elstar’ apples at harvest in 2006

Treatm.	L-value ¹		A-value ¹		B-value ¹		Firmness ² (kg)		Starch ³		Sugar (° Brix)		Acids (%)	
1	77.0	b	−7.7	a	47.4	c	6.7		5.2	a	14.4	d	0.82	b
2	75.1	ab	−8.8	a	45.6	b	6.5		5.2	a	14.1	cd	0.80	b
3	76.8	b	−9.6	ab	42.3	a	6.5		5.2	a	13.5	bc	0.77	b
4	73.5	a	−13.2	c	42.1	a	6.3		6.8	b	12.6	a	0.64	a
7	74.4	a	−12.4	bc	42.1	a	6.4		5.2	a	13.1	ab	0.68	a
F-test	$p < 0.05$		$p < 0.05$		$p < 0.001$		ns		$p < 0.01$		$p < 0.01$		$p < 0.001$	
LSD 0.05	2.0		2.9		1.6				0.8		0.8		0.06	

¹ Background colour determined by Minolta colorimeter: L-value, lower = darker colour; A-value, more negative value = darker green;

B-value, higher value = more yellow. ² determined at side with most intensive background colour by means of Instron penetrometer equipped with plunger with a diameter of 11 mm. ns = not significant. Values within a column followed by different letters differ significantly

Conclusions

The best chemical thinning treatment of this trial was the combination of 3 applications of ATS during flowering followed by BA at a fruit size of 13.8 mm. This treatment gave 82% of the thinning necessary to obtain the target fruit load. This treatment also effectively improved fruit size distributions, fruit colour and internal fruit quality. Slaked lime, applied with the aim of enhancing fruit drop by reduction of light interception by the leaves, did not thin Elstar effectively.

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